Rev. Écol. Biol. Sol, 1971, T. VIII, 1, pp. 111 à 117.

The ecological effects of moulting in Collembola

BY

N. D. DE WITH and Els N. G. JOOSSE

Department of Biology, Free University, Amsterdam, the Netherlands

Introduction

Moulting is an important process in the life of an Insect. In Collembola these events are especially radical, because these animals, in contrast with most insects, moult during their whole life. Besides, every ecdysis not only includes the shedding and replacement of the old cuticle but also a total regeneration of the epithelium of the intestine (PACLT, 1956).

In *Orchesella cincta* (L.) the forthcoming ecdysis is clearly visible, because the concerning animals doesn't move and doesn't eat. During this time of preparation, which takes a few days, the new cuticle is secreted. The ecdysis itself lasts a few hours. According to LINDENMANN (1950) the time of preparation takes 1-3 days in *Orchesella cincta,* whereas these animals moult every 4-5 days. A few hours up till one day after the ecdysis, the epithelium of the intestine is shedded.

During the time of preparation, when the animals have a double cuticle and during the ecdysis itself, when the soft new cuticle hardens, a very critical period must be bridged. Besides, these moults occur very frequently (at 20° C *Orchesella cincta* moults every 4.7 days, *Tomocerus minor* every 5.1 days and *Isotoma viridis* every 4.6 days (JOOSSE & VELTKAMP, 1970). An investigation was performed to study the effects of these moulting phenomena in populations of Collembola. Attention was paid to the condition of the gut with respect to feeding activity and to the state of the cuticle with respect to the mobility of the animals.

Methods

The investigations were performed on some epedaphic species from a fir plantation at Schiermonnikoog, one of the Dutch Wadden Islands. The investigated species were: *Tomocerus minor* (Lubbock), *Lepidocyrtus cyaneus* (Tullberg), *Entomobrya nivalis* (Linné) and *Orchesella cincta* (Linné).

The feeding conditions and the stages of the moulting process were studied in « cleared » animals. This « clearing » was carried out in a mixture of lactic acid, hydrochloric acid and a few cristals of potassium-chlorate (moderately heated). The « cleared » animals were used to determine 1) whether the gut was with or without any contents and 2) the stage of the newly secreted cuticle, which could be best established in the claws.

To determine the relation between the moult and the locomotory activity, moulting was synchronized by a starvation period of 5-7 days. In this period the animals were kept on humid, sterilized sand. Four or five days after the application of food (Greenalgae; *Pleurococcus spec.*) the animals moulted almost synchronously.

The locomotory activity in the laboratory was determined from the mean percentage of animals moving during 30 seconds. This kind of investigation has only been performed on *T. minor* and *O. cincta.*

The relations between feeding conditions and temperature and between locomotory activity and temperature were studied with *O. cincta.* Once a week, over a period of 16 months, the animals were collected from pitfall traps in a fir plantation at Schiermonnikoog. These specimens were « cleared ». In the same period, once a week, in the same plantation, the population density was estimated from the number of animals in soil samples treated in a Tullgren apparatus. The locomotory activity in the field was determined as the number of animals caught in the traps divided by the population density calculated from the soil samples of the same week. Each day in the investigation period the temperature was noted.

Results

1. *Moulting - empty gut.*

A great number of animals, from different times of the year, were immediately fixated at the sampling site. In these specimens, which were « cleared », the gut contents and the stage of the moulting process were determined. The results are presented in Table I.

TABLE I

The relation between feeding condition and moult in Collembola

Species	Number investigated	Empty gut		Distinct double cuticle		Empty gut + distinct double cuticle	
Orchesella cincta (April)	557	344	62 %	70	20 %	69	98%
Orchesella cincta (Febr.)	118	89	75 %	8	9 %	7	87 %
Tomocerus minor	114	84	58 %	14	17 %	14	100 %
Entomobrya nivalis	51	23	45 %	2	9 %	2	100 %
Lepidocyrtus cyaneus	39	32	82 %	—	—	—	—

From Table I it is clear that a high percentage of the animals possessed guts without any contents. A small percentage of the animals with empty guts possessed a double cuticle. On the other hand nearly all animals that showed a distinct double cuticle also had an empty gut.

A more detailed investigation with *O. cincta* revealed that in « cleared » animals different types of claws could be distinguished, which could be related to different moulting stages. Type 1 was found in all specimens that possessed guts with contents and type 3 could be found in all specimens with a distinct double cuticle; type 2 included all transitions from type 1 to type 3. Type 2 and 3 both represented a stage in the moulting process. The distribution of the different types of claws in 91 animals is presented in Table II.

TABLE II

Distribution of the types of claws in cleared specimens of *Orchesella cincta*

State of the gut	% of total	Type of the claws		
		1	2	3
With contents	64	100	—	—
Without contents	36	20	60	19

It is clear from Table II that a high percentage (79 %) of the animals with an empty gut can be correlated with the moulting process.

2. *Moulting and locomotory activity.*

In animals which were synchronized in their moulting by a starvation period of 5-7 days, the locomotory activity was determined during two moulting periods. These experiments have been performed with *T. minor* and *O. cincta*. The results are presented in Fig. 1. It is clear from this figure that the locomotory activity is low during the ecdysis and 1-2 days before the ecdysis. Immediately after the ecdysis the mobility increases.

3. *The effect of temperature on the feeding condition and on the locomotory activity.*

This investigation has been performed with « cleared » specimens of *O. cincta* from pitfall traps to study the content of the gut. At the same time the locomotory activity was determined, calculated from the number of animals caught in the pitfall traps devided by the population density in the same week. The relation between feeding condition, locomotory activity and temperature is presented in Fig. 2.

It is clear from Fig. 2 that the percentage of animals with empty guts as well as the locomotory activity can be related to the temperature.

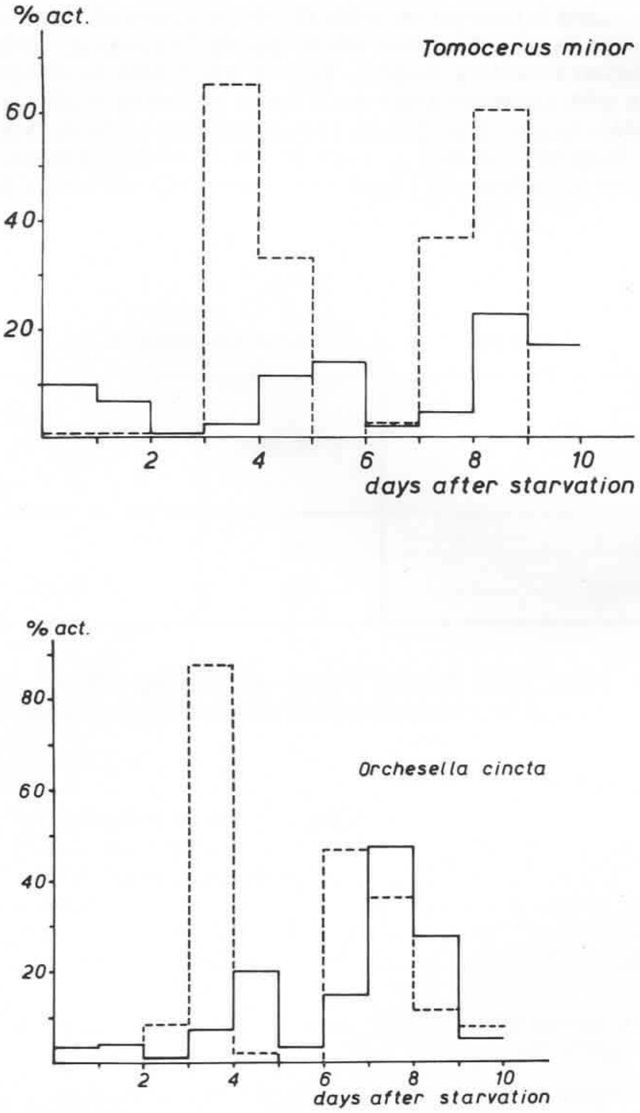

FIG. 1. — Locomotory activity in relation to moulting
——————— locomotory activity
- - - - - - - - moulting animals in % of total number)

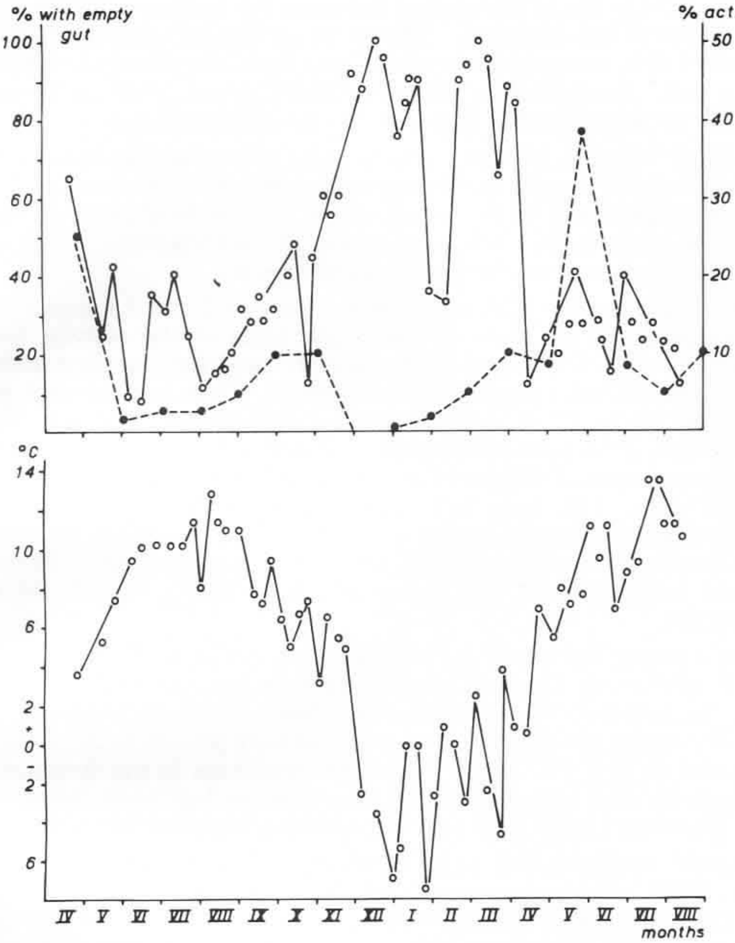

FIG. 2. — Relation between feeding - condition, locomotory activity and temperature in *Orchesella cincta*.
———— % animals with empty gut
- - - - - - - - locomotory activity

Discussion

From this investigation it is clear that in Collembola a relation exists between the feeding condition and the moulting process. It has been demonstrated that about 75 % of the animals with an empty gut are engaged with the moulting process (Table II). THIBAUD (1968), who studied the histological changes of the intestine during the intermoult, found that 60 % of the animals (Hypogastrurids) were in a phase, in which no food was taken. A part of the remaining 25 % of the animals with an empty gut may be related to the moulting process in another fashion, as in some specimens of this category a plug in the intestine was observed, existing of the degenerated epithelium, these animals may be in the period between the ecdysis and the shedding of the epithelium of the intestine. This is in agreement with the fact that some specimens of this category have claws that look like those of animals with a « filled » gut. According to THIBAUD (1968), about 10 % of Hypogastrurid species can be found in this phase of the moulting process.

The clear relation between empty guts and moulting indicates that the high percentages of empty guts observed by POOLE (1959) in several species of Collembola cannot only be the result of the kind of food eaten by the animals (i.e. bacteria, nematods). This suggestion of CHRISTIANSEN (1964) is at least incorrect with respect to the investigated species.

At 20° C *O. cincta* and *T. minor* moult every 4.7 and 5.1 days respectively. At this temperature the time of the preparation of the ecdysis takes about 2 days, as could be derived from the activity- and feeding-phenomena in synchronised populations (see also JOOSSE, 1971). Thus in a normal population of these species at 20° C each individual theoretically cannot feed during about 2/4.7 and 2/5.1 part of the time, respectively. This means that at 20° C 43 % of a population of *O. cincta* and 39 % of a population of *T. minor* should have empty guts. This is in full agreement with the work of THIBAUD (1968) on the histological changes in the intestine during moulting, and from which it can be concluded that about 40 % of the individuals of some Hypogastrurid species are engaged with any phase of the moulting process in which no feeding occurs.

These « empty » animals are locomotory inactive, so 43 % of *O. cincta* and 39 % of T. minor are theoretically locomotory inactive due to moulting phenomena. In practice the percentage inactivity in a population appears to be higher. The mean inactivity during two moulting phases at 20° C was 87 % for *O. cincta* and 91 % for *T. minor*. In field conditions in the summer, the locomotory activity also appeared to be very low, as has been demonstrated by JOOSSE & KAPTEIJN (1968) in activity-stimulating experiments with *O. cincta*.

At lower temperatures each moulting interval lasts longer (JOOSSE & VELTKAMP, 1970). It also appeared that the percentage of animals without gut contents becomes higher and that the locomotory activity becomes lower. It could be suggested that the relative duration of the preparation phase of an ecdysis should increase at lower temperatures. This is not supported by results of THIBAUD (1968), who found that in species with different moulting intervals the different phases last relatively equally long. During winter, at very low temperatures the locomotory activity is minimal, very few numbers of animals could be collected from the pitfall traps. It is even possible that these animals get into the traps by other means than walking, i.e. by wind, disturbances of the field by animals (birds, rabbits), or by men (JOOSSE & KAPTEIJN, 1968). All these animals had empty guts.

In general one may say that the locomotory activity which has an important survival value (JOOSSE, 1970), is highly limited by the moulting process. The moulting process in its turn depends on the feeding conditions, which is clear from the synchronisation effects. Besides the locomotory activity level, as well as the moulting rate are influenced by the temperature, as could be expected in these poikilotherm animals.

Acknowledgements

The authors are indebted to Mrs. E. VELTKAMP-KERKHOF and Miss L. M. ZUURHOUT for their valuable contribution in this investigation; and to Mrs. J. H. BUIJS-SWART for typing the manuscript.

SUMMARY

The ecological effects of moulting for populations of some surface dwelling Collembola were investigated. Locomotory activity which has important survival value appeared to be highly limited by moulting, whereas the moulting process in its turn depends on the feeding conditions. Both are controlled by the temperature.

LITERATURE

CHRISTIANSEN (K.), 1964. — Bionomics of Collembola. *Ann. Rev. Entom.*, **9**: 147-178.

JOOSSE (E. N. G.), 1970. — The formation and biological significance of aggregations in the distribution of Collembola. *Neth J. Zool.*, **20** (3).

JOOSSE (E. N. G.), 1971. — Ecological aspects of aggregation in Collembola. *Rev. Ecol. Biol. Sol.*, **8**: 105-111.

JOOSSE (E. N. G.) & J. M. KAPTEIJN 1968. — Activity-stimulating phenomena caused by field-disturbance in the use of pitfall-traps. *Oecologia,* **1**: 385-392.

JOOSSE (E. N. G.) & E. VELTKAMP, 1970. — Some aspects of growth, moulting and reproduction in five species of surface dwelling Collembola. *Neth. J. Zool.*, **20** (3).

LINDENMANN (W.), 1950. — Untersuchungen zur postembryonalen Entwicklung schweizerischer Orchesellen. *Rev. Suisse Zool.* **57**: 353-428.

PACLT (J.), 1956. — Biologie der primär flügellosen Insekten. Jena.

POOLE (T. B.), 1959. — Studies on the food of Collembola in a Douglas fir plantation. *Proc. Zool. Soc.* London, **132**: 71-82.

THIBAUD (J. M.), 1968. — Cycle du tube digestif lors de l'intermue chez les Hypogastruridae (Collemboles) épigés et cavernicoles. *Rev. Écol. Biol. Sol.*, **5**: 647-655.